10/519378

PCT/AU03/00926

Rec'd PCT/PTO 23 DEC 2004

REC'D 27 AUG 2003

WIPO PCT

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I, JULIE BILLINGSLEY, TEAM LEADER EXAMINATION SUPPORT AND SALES hereby certify that annexed is a true copy of the Provisional specification in connection with Application No. 2002950395 for a patent by JULIETTE HARRINGTON as filed on 26 July 2002.

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JULIE BILLINGSLEY
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Title

SOLAR MAGNETOHYDRODYNAMIC POWER GENERATION

Field of the Invention

This invention relates generally to the terrestrial and space application of electrical power generation from solar energy. In particular, although not exclusively, the invention relates to magnetohydrodynamic (MHD) power generation utilising both direct and diffuse solar radiation provided by a static compound solar collector specifically adapted for that purpose, although the solar collector of the invention will find use in other process heating applications.

Discussion of Prior Art

It is accepted that demand will continue to increase for energy both terrestrially and in space. Rapidly depleting fossil fuels cannot in the long run fulfil the ever increasing demand for energy. Further the use of fossil fuels has a detrimental effect on the environment. Nuclear power plants have the added risk of potential accidents with disastrous consequences for both human life and the environment. Both nuclear power plants and hydroelectric plants have very high capital construction costs. These high costs not only increase the unit cost of electricity for the consumer but also prevent many third world countries from generating electricity for domestic and particularly industry use in areas where power supply is most needed to generate industry, jobs and raise the average standard of living.

The use of photovoltaic technology, such as solar cells, is generally effective in producing small amounts of electricity. It is theoretically possible to produce large scale electricity using vast arrays of photovoltaic cells. This would require the covering of very large tracts of land which would not only be very expensive due to land costs, but would be a poor environmental and agricultural use of land, not to mention aesthetically unappealing. The cost and technology required for delivering a large array of photovoltaic cells into earth orbit tends to be prohibitive. The use of concentrators with photovoltaic cells is limited due to the decrease in efficiency corresponding with the increase in heat

from the concentrator. Thus the advantage of a high level of radiation using concentrators is lost when using photovoltaic cells. Similarly, other design complications also arise and thus unit cost is greater for photovoltaic cells using concentrators, since tracking devices and other modifications to the cell for cooling purposes must be made.

Certain prior art patents, in particular dating back to the 1970's and early 1980's, envisage the use of solar energy combined with a magneto-hydrodynamic (MHD) energy conversion system. See, for example, US Pat. No. 4,095,118 (Rathbun) issued June 1978, US Pat. No. 4,191,901 (Branover *et al.*) issued March 1980, US Pat. No. 4,275, 318 (Duncan) issued June 1981 and US Pat. No. 4,388,542 (Lee *et al.*) issued June 1983. However, these patents refer only to solar collectors, mentioning only heliostats and reflectors. This patent seeks to address this gap in knowledge.

Since the 80's advancements have been made in solar concentrators, both in terms of design and cost of manufacturing and particularly for use with photovoltaic cells, such as described in the following references:

"Solar Voltaic Cells" by W.D Johnson, Jr., *Energy, Power and Environment, Vol.7;* P.N. Powers (Ed.) New York: M. Dekker, 1980;

"Concentrating Systems" by M.A. Green, *Solar Cells – Operating Principles, Technology and System Applications, Ch.11*, University of New South Wales, Feb 1992;

"The Sun and Sunlight" by R.C. Neville, *Solar Energy Conversion, (Second Edition), Ch II*, Elsevier, 1995; and

"Light Trapping" by M.A. Green, *Silicon Solar Cells – Advanced Principles & Practice, Ch. 6,* University of New South Wales, 1995.

However, these advances have not been applied in the way now envisaged by the present inventor. In particular, the inventor has realised that the disadvantage of excess heat for photovoltaic cells that is generated by the use of concentrators can thus be turned to advantage when powering a MHD system, wherein high levels of heat are necessary for operation. Furthermore the safe, cost effective and environmentally sound opportunity exists to generate electricity on a large scale, for both reserve and/or power plant production using solar radiation.

Object of the Invention

It is an aim of the invention to provide a compound solar concentrator for use in combination with a magnetohydrodynamic (MHD) energy conversion system.

It is another aim of the invention to provide a static solar concentrator that can utilise both diffuse and direct sunlight for power generation and/or process heating applications.

A further aim of this invention is to provide for storage of solar energy for release back into the MHD system.

Still another aim of this invention is to provide a cost effective alternative method of producing large amounts of electricity suitable for third world and developing countries.

Lastly an aim of this invention is to provide a method of producing large amounts of electricity that is environmentally sound.

Other aims and advantages of this invention will become apparent hereinafter upon reference to the following description and drawings.

Summary of the Invention

In one form of the present invention, there is provided a multi-stage solar concentrator in combination with a solar oven for a magnetohydrodynamic (MHD) electrical power generation system, said combination including:

a planar solar collector for collecting ambient solar radiation, said collector associated with a compound parabolic solar concentrator that together form the multi-stage solar concentrator;

a solar oven adapted for use in a fluid circuit of the MHD system and for receiving concentrated solar energy from the solar concentrator; and

whereby, in use, the solar concentrator provides sufficient radiative energy to at least partially ionise the working fluid contained in the solar oven.

In another form, the invention resides in a solar concentrator for use in process heating applications, said concentrator including:

a static planar solar collector;

a paraboloidal mirror receiving photons from the planar solar collector; and

a compound parabolic solar concentrator receiving photons from both said planar solar collector and said paraboloidal mirror.

The planar solar collector is suitably static and may incorporate a Fresnel lens, or a luminescent dopant for shifting the wavelength of incident solar radiation. Preferably, the wavelength of the incident solar radiation is shifted predominantly into the wavelengths suited to ionising said working fluid.

The luminescent dopant suitably comprises a dye.

The planar solar collector may further include a base having a reflective geometrical scheme, suitably comprising an array of tilted pyramidal reflectors, for redirecting radiation into the throat of the compound parabolic solar concentrator.

Preferably the solar concentrator further includes a paraboloidal mirror, suitably disposed between the planar collector and the compound parabolic stages of the solar collector. Suitably the paraboloidal mirror reflects radiation redirected by the pyramidal array.

If required, interior surfaces of the solar concentrator may be coated with a heat resistant gel, suitably comprised of an anionic water absorbent polymer.

Preferably the solar concentrator is a hermetically sealed module constructed from a dielectric material.

In a further from of the invention, there is provided a magnetohydrodynamic (MHD) electrical power generation system powered by solar energy, said system including:

a multi-stage solar concentrator as set out above for collecting and concentrating ambient solar radiation;

a solar oven arranged in a fluid circuit of the MHD system and coupled to the solar concentrator whereby, in use, sufficient radiative energy is provided by the solar concentrator to at least partially ionise the working fluid contained in the solar oven;

said fluid circuit further including -

an electrode chamber for accelerating the ionised working fluid in order to generate electrical current,

a seeding device for injecting a seed material into said working fluid,

a separator coupled to the electrode chamber for separating the seed material from the working fluid for return to the seeding device,

a regenerative heat exchanger coupled to the separator for recovering heat from the working fluid, and

a compressor supplied by the heat exchanger and a gas source for returning the working fluid to the solar oven.

Preferably the seed material comprises statically charged particles, such as carbon particles. A subsidiary photovoltaic array may be provided for supplying voltage for charging said particles.

The fluid circuit may further include a storage chamber for storing excess heated working fluid. The excess heated working fluid may be supplied to the storage chamber directly from the solar oven or indirectly from the heat exchanger in the fluid circuit. Working fluid from the storage chamber may be re-introduced into the fluid circuit via the compressor.

Preferably a second solar concentrator is coupled to a radiator associated with the storage chamber for providing further thermal energy to said chamber.

If required, a plurality of solar concentrators could direct radiative energy through one or more foci a plural number of times to ionize said working fluid to provide moving charged particles, which particles are compressed by a magnetic field and directed through the MHD electrode chamber for the generation of electricity.

Preferably a closed Brayton cycle will be utilised for this system.

An alternative cycle that may be considered is a Rankine cycle liquid MHD generator. In such as generator, one or more liquid may be combined with one or more gas, which may be seeded directly into the solar oven, storage container, compressor and/or duct. The liquids and/or gases may be separated. After separation the gases may pass through to the regenerative heat exchanger whereas the liquids may pass directly to the compressor. The

liquid/s and gas/es are heated in the solar oven by photons collected by the solar collector/s.

Preferably the multi-stage compound collector may consist of, for example but not limited to, a planar collector, paraboloid reflector and a compound parabolic collector. These examples would be capable of providing large scale power when used with a MHD system in space and/or on earth.

The system described above can easily be modified for application on earth or space.

The solar concentrator may comprise an array of solar collectors each attached to MHD generators to produce large amounts of power. Scalable solar MHD generators may be built to cater for the different types of electrical output required.

Preferably a temperature regulating device is attached to the concentrator to monitor variations in solar radiation subject to cloud interruptions and periods of darkness.

Preferably the concentrator would as solar intensity fluctuates according to the temperature requirement, filter and/or further concentrate the suns photons passing into the solar oven thus sustaining the temperature for maximum operation efficiency.

A number of methods can be utilised to achieve this type of temperature regulation including but not limited to, the use of compound collectors where one or more of the planar collector/s can be added or removed at any one time. Also there may be use of chemical coatings on the collector that are activated or deactivated according to the temperature in the solar oven. Similarly a radiation wave sensor could be utilised where only certain wavelengths can be accepted for example by splitting the spectrum.

Alternatively one or more concentrator(s) with two or more foci could be utilised. Potentially this may be more cost effective than having two or more collectors with individual foci. The collector could heat the working fluid in the solar oven from one foci point. Then for example, the remaining foci point/s could direct to the radiator and/or to the gas/es in the storage chamber. Alternatively a plurality of foci could direct radiative energy into the solar oven by splitting the spectrum, with the sum of all split wavelengths being directed

from each foci into the solar oven only or a portion of wavelengths to, for example, the radiator or storage container.

Brief Details of the Drawings

In order that this invention may be more readily understood and put into practical effect, reference will now be made to the accompanying drawings that illustrate preferred embodiments of the invention, and wherein:

FIG. 1 is a cross-sectional side elevation of a solar collector and solar oven of an embodiment of the present invention;

FIG. 2 is a block diagram representing a solar MDH system of a first embodiment;

FIG. 3 is a block diagram representing a solar MHD system of second and third embodiments; and

FIG. 4 is a cross-sectional side elevation of a solar collector and radiator associated with certain embodiments of the invention.

Description of the Preferred Embodiments

Referring to FIG. 1, a multi-stage solar collector 10 comprises a planar collector 11, a paraboloidal mirror 12 and a non imaging compound parabolic concentrator 13. Thus a combination of lens and mirror systems is utilised in the multi-stage collector 10, which is coupled to a solar oven 15 in the embodiment. Although the lens comprised by the planar collector 11 and transparent window 14 into the solar oven 15 may be composed of quartz, glass and plastic are both cheaper. Glass is opaque for selected spectral regions in the infrared and only for ultraviolet wavelengths less than 0.38 microns.

In order to provide efficient light transmission in desired wavelengths with low reflection, tailored plastics such as vinyl and polyethylene can be utilised. When exposed to sunlight and various weathering elements glass is heavy while plastic is light while both have proven to be durable. A low-index (less reflection) of refraction material is desirable in a lens. Antireflection coatings may be utilised but may be exposed to weathering problems and can increase the cost of construction.

In the embodiment, a planar fluorescent collector 11 comprises the first stage of collecting and concentrating of incident solar radiation. Either a single transparent sheet or a plurality of transparent sheets arranged in a stack, wherein the sheets of material are doped with a fluorescent dye. Other wavelengths, in the range from x rays to gamma rays, are re-emitted after the incident radiation is absorbed. The advantages of the fluorescent doping are that diffuse light can be concentrated and that the collector can be operated statically.

In this example a sheet of glass or plastic 17 is doped with a luminescent substance and all four edge faces 16 of the sheet are made reflective using a metal such as aluminium or some alloy. It is possible to evaporate a thin reflective surface or use a sheet of metal over some adequately smooth substrate. The first technique has the disadvantage of being exposed to chemical weathering processes and abrasion due to the production of front surface mirrors. One solution is to use second surface mirrors. Behind a transmissive material such as quartz, glass or plastic a reflective layer is placed that protects the reflective layer and acts as the mirror substrate. The disadvantage occurs from transmission losses as light passes through the protective layer.

By utilising a planar collector 11, all angles of incidence of solar radiation can be accepted. On a base surface of the luminescent planar concentrator 11 geometrical reflective schemes 18 using tilted pyramids can be utilised. The tilted pyramid scheme 18 would only cover that portion of the base surface outside the angle of acceptance of the parabolic reflector 13. In this way the incident sunlight that does not pass directly through the planar concentrator 11 to the parabolic concentrator 13 will be reflected from the sides of the planar concentrator eventually back to within the angle of acceptance (typically 34 degrees) of the parabolic concentrator 13. Within the sheet(s) 11 a large fraction of the emitted light is trapped, either by reflection from the reflective edges 16 or by total internal reflection, until it reaches the acceptance angle of the attached parabolic reflectors 12, 13. The photons will then continue to reflect within the parabolic mirror 12 until they reach the angle of acceptance of the compound parabolic reflector 13.

Direct sunlight generally has a different spectral composition from diffused sunlight. The latter is generally richer in the shorter or "blue" wavelengths. However, there is no mandate on the direction of distribution of diffuse radiation from the sky. This distribution introduces other uncertainties when collecting solar radiation on inclined surfaces, since radiation levels are calculated from data recorded on horizontal surfaces. In temperate climates more than 40% of solar insolation consists of diffuse sunlight.

Approaching the maximum possible, non imaging compound parabolic collectors 13 are capable of extremely large concentration ratios. At high ratios the area for the reflecting surface for a given entrance aperture area becomes unacceptably large. In order to attain better overall efficiency light may be first concentrated by a paraboloidal mirror 12 and then further concentrated by a non imaging device. This three stage optical concentrator 10 consisting of a planar collector, a primary paraboloidal mirror and a non imaging compound parabolic concentrator brings sunlight into the entrance throat of the transparent glass window 14 of the solar oven 15. Thus the detrimental affects of surface imperfections and aberrations are minimised when compared to a single high ratio paraboloid.

The non imaging compound parabolic concentrator (CPC) 13 is considered as having a substantially ideal performance. The goal is to have an acceptance angle as large as possible. For the parabolic to maintain a sharp focus the incoming light rays need to be as close as possible to parallel to the optical axis 19. For the same degree of concentration an all dielectric CPC, which for concentration utilises total internal reflection, has a great acceptance angle. These concentrators could be cast of acrylic plastic which shows good resistance to ultra-violet light and has a refractive index ~1.5. An all-glass or plastic truly hermetically sealed module for the collector 10 is desirable. As previously stated, the focus of the parabolic mirror is sharp for all light rays entering parallel to the optic axis 19. However if the incoming light rays are not parallel to the optic axis the focus point will shift. An ellipsoidal focal volume is the result.

There is a voluminous amount of literature and patents dealing with MHD systems and, in the current context, there exists too large a choice of system

methods to allow even a summary discussion of them. Several examples were mentioned above in the background section. As is well understood, such systems typically involve the production of plasma, which flows between electrodes within a magnetic field. The plasma, which can be a high temperature gas and/or liquid, is fully or partially ionised and contains ions, electrons and (if partially ionised) neutral particles. The electric and magnetic fields enable the dynamic behaviour of the charged particles to respond. In essence a moving stream of plasma flows through a magnetic field normal (orthogonal) to the flow direction of the stream, oppositely charged particles are enacted upon opposing forces in the third orthogonal direction. Charged particles induce a flow of electrical current in appropriately placed electrodes and circuit means.

The three stage compound parabolic collector 10 supplies radiative energy of sufficient intensity to produce moving charged particles from the selected MHD working fluid. Through a combination of thermal excitation and photon excitation the working fluid is excited to an ionised state by the concentrated solar energy. The thermal excitation elevates the statistical energy level of the molecular and atomic working fluid to a level at which it is photon responsive, which energy level is preferably substantial but at least partially the working fluid can be photo-ionised to form plasma. Through charge transfer processes the working substance is ionised by the radiative energy whereupon the resulting charged particles are kinetically energised.

The ionisable working fluid may include but is not limited to one or more of the following gas selected from the group consisting of helium, neon, argon, krypton, xenon, radon and steam (water). Compressed air may also be considered a suitable gas and could be utilised in this process. Similarly the ionisation of the gases may be enhanced by the addition of a seeding material such as an alkali metal, for example lithium, sodium, potassium, rubidium, caesium, fraconium and salts may be utilised.

As discussed in relation to FIG. 1 above, the solar oven 15 is attached to the base of the compound solar collector 10. The collected photons are focused onto a circulating opening through reflector which is covered by a transparent window. Turning to FIG. 2 the solar oven 15, which may be frustro-

conical in shape, is attached to and covers the window 14. The walls of the solar oven can be made of rings of reflective material (for example, stainless steel) which can withstand a temperature greater than 1000K. The taper of the inside surface of the solar oven suitably fits the taper of the focus of the photons reflected by the focusing collector 10.

The MHD generator 20 includes a power conditioning unit and a chamber 21 associated with a superconducting magnet for generating a magnetic pinching field. The field encloses the chamber 21 for directing and concentrating of moving charged particles into an MHD electrode system often incorporating an MHD duct 22. The charged particles remaining in the solar oven 15 enter the duct 22 where, through the magnetic pinching field in the MHD electrode chamber 21, the concentrated charged particles are directed. Electricity is generated as the working fluid, such as a gas, travels through the electric magnet field created by the magnet. This process occurs where the charged particles flowing form the duct 22 are magnetically directed across opposing electrodes 23 producing a potential difference between them. Via an electrical circuit this potential difference can drive an electrical current through an external load 24. It is necessary to state that the MHD generator of the embodiment produces direct current. It is preferable for the distribution system to include inverter means of a conventional nature to change the direct current into alternating current for more efficient distribution of electrical power to users.

A separator 25 is attached to the output of the MHD chamber 15. The centrifugal separator 25 separates the gases that pass through the MHD chamber 15 from seed material, as discussed below. The gases output by the separator 25 then pass through a regenerative heat exchanger 26 to a radiator 27 which rejects excess heat. The seed material output by the separator 25 is, in contrast, passed back to a seeding device 28.

The radiator 27 is attached to the regenerative heat exchanger 26 which in turn is attached to the solar oven 15. A gas source 31 provides a flow of working gas directly into a compressor 20, and then to the regenerative heat exchanger 26. From the radiator 27, the working gas also then passes through the compressor 30 and back through the regenerative heat exchanger 26 to the solar oven 15. If required, the working gas may be radially injected into the

oven close to window 14 by means of several nozzles. A gas source 31 and a valve supply the gas to the compressor 30 where the gas is compressed for start-up of the MHD system 20.

The operation of the embodiment of the invention shown in Fig. 2 will now be described in further detail. The sunlight photons are collected by the compound solar collector 10 and reflected onto the solar oven 15. The charged particles remaining in the solar oven 15 enter the duct 22 where the concentrated charged particles are directed through the magnetic pinching field and into the MHD electrode chamber 21. Seeding material, which might preferably include carbon particles as discussed below, are injected into the duct 22 by the seeding device 28, which draws seeding material from a suitable supply 29.

As the seeded gas travels through the electromagnetic field created by magnet, electricity is generated in the manner known to MHD systems. A centrifugal separator 25 is attached to the output of the MHD chamber 21 for separating the gases that pass through the MHD chamber from the seed material. The working gas output by the separator 25 then passes through the regenerative heat exchanger 26 to the radiator 27. The gas source 31 provides a make-up flow of gas to the solar oven 15 via the compressor 30 and the regenerative heat exchanger 26. This completes the cycle and demonstrated how the working gas/es is/are recycled in the system.

Diffuse sunlight is generally ineffective for standard concentrators. With reference to Fig. 1, a planar concentrator 11 utilises internal reflection light trapping as well as fluorescent energy conversion of photons to lower energies. The dopant absorbs incident sunlight which is then re-emitted by luminescence in a narrow-wavelength range. The fluorescent dyes that are dissolved in a large acrylic or glass sheet 17 absorb the incident sunlight. The photons are then emitted by the dyes with energies lying in a relatively narrow band centred in the 1 – eV range.

The fluorescent dyes are selected to enable the emission spectrum to be displaced from the absorption spectrum to reduce reabsorption losses. Within the absorber at the surface most of the photons emitted suffer total internal reflection. Such planar concentrators accept light from a wide range of

incidence angles as well as having large geometrical concentration ratios (~200).

A planar collector theoretically accepts all angles of incidence. Only practical considerations such as absorption of the emitted light in the sheet limit maximum concentration. The luminescent collector 11 works by absorbing photons from the solar spectrum and emitting longer wavelength photons in randomised directions. The aim through good design is to trap most of these longer wavelength photons inside the plate 17 by total internal reflection. The four edges 16 of the plate 17 are polished and silvered. With this design it is theoretically possible to achieve concentrations of several hundred. One problem to be addressed is that of reabsorption losses in the luminescent medium. Also a disadvantage to be considered is that the life of the dyes is short. The ideal organic dyes would have high fluorescent yield with low decomposing probability.

Sunlight is presented to a direct optical concentrator 10 as a bundle of rays. These rays enter the concentrator through a large aperture and condense these rays to pass through a small exit aperture. Since brightness cannot be increased in a refractive or reflective optical system the beam must become divergent during this process. Brightness is a property of the radiation source eg. the sun, and is measured in watts per cm^2 per steradian of divergence. The angular tolerance varies inversely with the concentration ratio.

In the embodiment of Fig. 2, the focused photons are transmitted through the transparent window 14 to the solar oven 15. The window 14 is constantly cooled and maintained clean by the radial flow of the working gas flowing through nozzles. The working gas molecules partially absorb the photons while they flow through the conical volume of the solar oven in which heating and compression of the gas takes place. The gas/es may be heated to a higher temperature than necessary for the operation of the MHD system. The excess heated gas generated passes through a heat exchanger 26 to the radiator 27 whereupon the energy may be stored, as discussed below in relation to Fig. 3, until it is required during for example the hours of darkness.

The compound collector 10 produces moving charged particles by supplying radiative energy of sufficient intensity to the working fluid. The

radiative energy ionises the working fluid by charge transfer processes and, in addition, imparts kinetic energy to the resulting charged particles. Charged particles are not produced by chemical reaction but instead are produced by charge transfer processes. This is an important distinction as this example illustrates how combustion and thus the burning of fossil fuels are not required in the present invention. Instead, radiative energy is directly converted into electrical energy without combustion reactions. This method utilising charge transfer ionisation produces non-equilibrium plasma which can be recombined and reused in a fully enclosed system. Charge transfer processes cause an ejection of an electron from a neutral atom and recombination brings the atom back to its neutral state where it can be used again.

In operation concentrated along the longitudinal axis of enclosure the superconductive magnet is activated to form the magnetic pinching field. Ionisable working substances for example but not limited to caesium or compressed air diffuses as gas into the solar oven and is directed through to the magnetic pinching field. Radiative energy directed through the transparent window into the solar oven by the compound concentrator impinges for example on the compressed air atoms. These atoms are ionised by charge transfer processes and imparting kinetic energy to the charged particles of the resulting non-equilibrium plasma. The magnetic pinching field interacts with the moving charged particles and directs the plasma along the longitudinal axis of the MHD chamber.

A relatively high pressure is produced by the magnetic pinching effect, combined with an increase in temperature due to magnetic compressing and radiation excitation pressures. This high pressure directs the charged particles along the axis of the duct 22, through the aperture and the MHD electrode system 21 where a potential difference is produced between the opposing electrodes 23 and in accordance with the conventional magnetohydrodynamic principles. Upon contacting the electrodes the for example caesium or compressed air ions recombine to form neutral atoms.

In an alternative embodiment of the invention, shown in Fig. 3, a storage container 32 is used to hold excess gas/es, which may pass from the compressor 30 to the storage chamber 32 then back to the compressor 30 to

the solar oven 15 via the regenerative heat exchanger 26. In addition, as shown by the dashed line, if excess gas/es are heated in the solar oven 15 on reaching a required temperature the gas/es may pass from the solar oven 15 directly to the storage container 32. The gas/es, when required, then return via the compressor 30 and the regenerative heat exchanger 26 to the solar oven 15. In a further alternative, a second collector 33 is utilised for focusing radiant solar energy onto the gas/es in the storage chamber 32. When needed the gas/es pass to the solar oven 15 via the compressor 30 and the regenerative heat exchanger 26. All other parts of the embodiment of the invention are like those disclosed in relation to Fig. 2.

The storage chamber 32 could be a natural cavern or a container both utilising any number of materials known for their insulating qualities. For example but not limited to stainless steel reinforced with copper or concrete reinforced with steel wool. Ceramics and heat retardant gels may be utilised to insulate either a man made storage container or a natural cavern. Potentially one or more gels could be used to coat, for example but not limited to, the solar oven 15, storage chamber 32 and the MHD chamber 21 to increase the maximum temperatures of the gas/es that may be stored or passed through. These gels may be made from super-absorbent polymers and act as a thermal protective coating similar for example the fire gels used by fire fighters to mitigate fire damage and marketed by Barricade International, Inc. under that trade mark. This particular "Barricade" gel for instance can withstand temperatures of almost 2000C and can successfully block out fire and heat.

Potentially the solar oven could include a dividing wall that is lifted incrementally or not prior to the hours of darkness so that the additional volume of air can be heated by the collector 10 in the exemplary, steel insulated chamber. The dividing wall could have a filter that the air could flow through, such as Venetian type blinds or a duct.

The operation of the embodiment of the invention shown in Fig. 3 is as follows. The working gas is separated in the separator 25 and is heat is recouped from the gas in the regenerative heat exchanger 26. The gas then travels to the storage container 32 and back to the solar oven 15 via the

compressor 30 and regenerative heat exchanger 26. Storage of the working gas is generally required during the hours of darkness.

In addition, the collector 10 may heat a volume of air required to pass through the MHD chamber 21 as well as potentially for example, extra gas in the original solar oven 15. When the extra gas is heated, that extra amount passes to the storage container 23 direct from the solar oven 15 (as indicated by the dashed line) then back via the compressor 30 and the regenerative heat exchanger 26 to the solar oven 15.

Furthermore, the storage container 32 may be large enough to be filled with sufficient gas to provide the required volume to produce electricity through the entire night, which is heated by the second solar collector 33. This allows the capacity of the solar oven 15 to be smaller and less expensive. The second solar collector 33 focuses radiant energy onto the gas/es in the storage chamber 32. When needed the gas/es pass to the solar oven 15 via the compressor 30 and the regenerative heat exchanger 26.

The storage of solar energy for use with a MHD system 20 is also addressed in this patent. Storage for photovoltaic cells has been largely ineffective due to the small amount of radiation that is utilised per cell. Any discussion in prior art of the storage of solar energy has been brief. Similarly the central power grid can provide a back-up system, where it is accessible, suitable for photovoltaic systems.

Such possibilities are not exempted from this invention, but are further expanded upon for example with the introduction of the use of a radiator 40, as illustrated in Fig. 4. The radiator may be used to generate energy and/or to store excess heated fluid whether a gas liquid or a mixture of phases, which may be heated using a compound collector 41, attached to a solar oven 42. Preferably a second compound concentrator may be attached to the radiator in a similar fashion to the thermophotovoltaic (TPV) method. In particular, the concentrator heats the radiator 40, which in turn transfers thermal energy to any fluid passing through the solar oven 42.

Thus this method has been converted from a photovoltaic type for the utilisation of the generation of electricity using the solar MHD method for downtimes and during the hours of darkness. Other more conventional high

Unlike photovoltaic cells, the MHD solar process enables all radiation wavelengths to be utilised. Radiation is partially absorbed by the working gas molecules in the solar oven 15. In this example a photovoltaic cell (not shown) is utilised to provide the required voltage to the solar oven to ionise carbon particles. The rear of its cell is made highly reflective so that long-wavelength radiation passing through it is reflected back to the radiator and/or into the solar oven. This is a particularly useful and efficient utilisation for periods of darkness and/or downtime. All other parts of the third embodiment of the invention are like those disclosed in Fig. 2.

The operation of the third embodiment of the invention is as follows. Carbon particles are seeded into the gas flow and a voltage source (not shown) sends electrostatic charges into the solar oven 15, whereby carbon particles present in the gas flow are electrostatically charged as the gas flows into a magnetohydrodynamic generator where they function as charge carriers in the MHD process. A corona discharge is initiated between electrode and the inner wall surface of cylinder by applying a sufficiently high voltage to the electrode from supply, the voltage for such purpose being dependent on factors such as the spacing between electrode and cylinder and gas composition, temperature and pressure but typically being around 20 kilovolts. The corona discharge ionises the gas in the region between electrode and cylinder and the resulting ions impart an electrostatic charge to the carbon particles by charge exchange.

In this example the gas ionisation does not persist to a significant extent after the flow leaves the charging device. Recombination of such ions with free electrons occurs rapidly, as the gas flow temperature is well below that needed to sustain equilibrium ionisation. Thus the momentary ionisation or plasma formation which occurs within the charging device does not serve solely to provide the electrical charge carriers required for operation of the MHD generator. This allows the excess radiant energy to be utilised for storage as outlined in earlier embodiments and enables MHD power generation without the high gas temperature needed to sustain ionisation and without the costs and complications involved in introducing and then recovering ionisable alkali metal seed material.

The hot gases from the electrostatic charging device are directed into the MHD generator which may be of known structural configuration, although as herein described, the charge carriers to which the generator reacts may be carbon particles solely rather than the conventional plasma of ions and free electrons or a combination thereof. Such generators produce electrical energy, in the form of DC current, from the kinetic energy of the gas stream. One important feature of the MHD generator of this embodiment is that it may be operated at temperatures lower than traditional MHD generators. This lower operating temperature is made possible because the gas temperature itself is no longer relied upon solely to provide charge carriers by thermal ionisation of the flow gases. Charge carrier density in the MHD generator is not determined solely by temperature. It is a function of the carbon particle density in the gas flow and the voltage that is applied to the electrostatic charging device.

In thermophotovoltaic solar energy conversion sunlight is used to heat a radiator to high temperatures whereupon the radiator re-emits radiation onto a solar cell. The thermophotovoltaic cell offers anther possibility of using some of the infrared energy which might otherwise be wasted. In a further preferred embodiment of the present invention, a high ratio optical concentrator 10 is used to collect and concentrate sunlight that is then used to heat a secondary radiator at a lower temperature than the solar surface. For photovoltaic conversion, less radiant energy is then present at short wavelengths above the solar cell band-gap. To maintain the radiator temperature it is possible to recycle infrared energy not absorbed in the photovoltaic cell. In this embodiment the photovoltaic cell is used to provide voltage to the carbon particles in the solar oven. In addition the radiator may continue to provide energy directly to the solar oven to ionise the working substance as outlined in relation to the embodiment illustrated in Figs. 2 and 3. In this way all radiation wavelengths may be utilised.

Radiation is partially absorbed by the working gas molecules in the solar oven 15. Similarly, where a photovoltaic cell is utilised to provide the required voltage to the solar oven to ionise carbon particles the rear of its cell can be made highly reflective so that long-wavelength radiation passing through it is reflected back to the radiator and/or into the solar oven. This would be a

particularly useful and efficient utilisation for periods of darkness and/or downtime. The infrared radiation not used to create electron-hole pairs must be reflected back to the radiator and/or into the solar oven if high overall efficiency is to be obtained.

Advantages of certain embodiments of the present invention over prior art are numerous. Abundant solar energy available both in space and for regular prolonged periods on earth is utilised in the invention. Solar energy contributes positively to the environment as it does not cause pollution and is sourced from a relatively unlimited supply unlike rapidly depleting fossil fuels. The utilisation of solar energy is cost effective with significant capital and operating savings expected for the invention.

A high efficiency results from the invention compared with the prior art such as solar cells, and thermoelectric power generation in space as well as wind power on earth. The lack of combustion for this invention reduces cost, safety and pollution risks. Due to this lack of combustion, high supersonic speeds of the plasma are not required which allows the use of a lower temperature, a lower speed and thus minimal wear on materials. There is also a reduction in the control and maintenance of electrical discharges.

In comparison to most of the prior art this invention can be operated at relatively lower temperatures (1000K) rather than temperatures exceeding 2000K. As previously stated, the lower the operating temperature of the process, the less likelihood of materials problems. However advancements in materials now allow tolerance of higher operational temperatures. Such advancements enable the excess temperature to be utilised for storage for the operation of the MHD process during darkness and/or periods of downtime.

Another advantage is the possible use of air as a constant compressed gas, which is the cheapest gas on earth. Similarly for space applications the surrounding medium in space can be ionised by photons. For example from deep in space a vacuum has high ionisable qualities. For earth-bound applications, any oxygen in the atmosphere can also be utilised for seeding. Other oxides or seeding materials can be added to the vacuum for combustion and to increase ionisation. Any of the above MHD cycles mentioned can be open or closed, and utilise the Brayton or Rankine cycles.

Whilst the above discussion of embodiments of the invention was primarily in the context of solar energy and MHD energy conversion, the general techniques described are equally capable of application in a generalised energy conversion environment as will be clear to one conversant in the technical field. For example a solar MHD generator of the invention could be configured to power a vehicle, including providing an engine for powered flight, or other aircraft, ships or spacecraft.

As noted in the background discussion, it is common for solar collectors to be used for photovoltaic and for MHD conversion systems to be used to generate electricity. However, individual photovoltaic cells produce only small amounts of electricity and even when large arrays of photovoltaic cells are combined the total amount of electricity generated is small and costly when compared to other large scale energy producers. Similarly with the use of large arrays of photovoltaic cells large tracts of land would be needed. MHD energy conversion systems and other large producing energy systems such as hydro and nuclear plants historically have required an abundant use of expensive and depleting fossil fuels. With the rapid increase of energy required throughout the world large scale non fossil fuel energy sources are needed. With the technological advancements in the collection and generation of solar energy vast improvements have been made that now make it practical to pursue the generation of reserve and large scale solar energy. Continued advancements in the area of solar energy will only contribute to the efficiency and practical economics of this invention.

It is to be understood that the above embodiments have been provided only by way of exemplification of this invention, and that further modifications and improvements thereto, as would be apparent to persons skilled in the relevant art, are deemed to fall within the broad scope and ambit of the present invention described herein.

Dated this TWENTY-SIXTH day of JULY 2002

JULIETTE HARRINGTON

by

PIZZEYS Patent and Trade Mark Attorneys

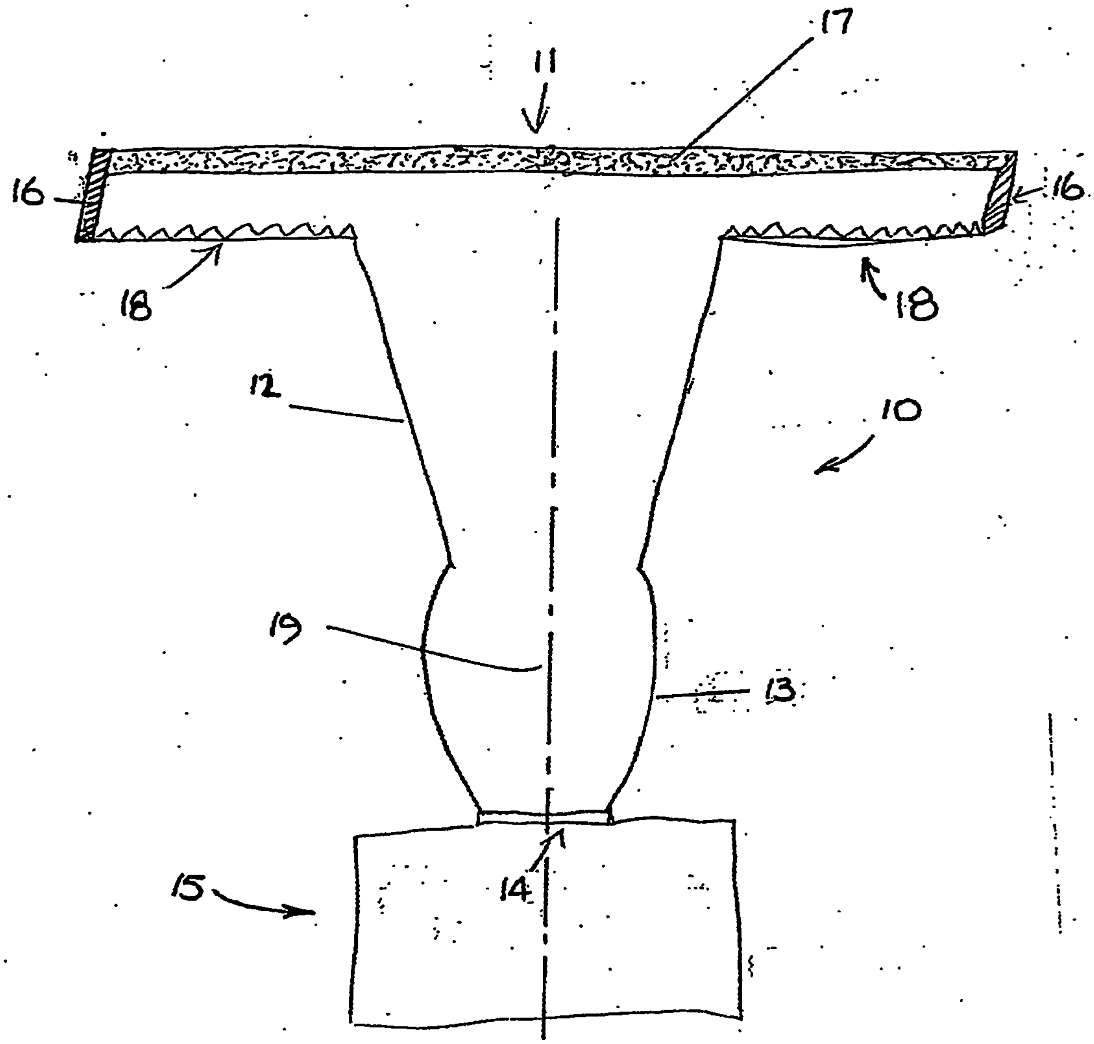

FIG. 1

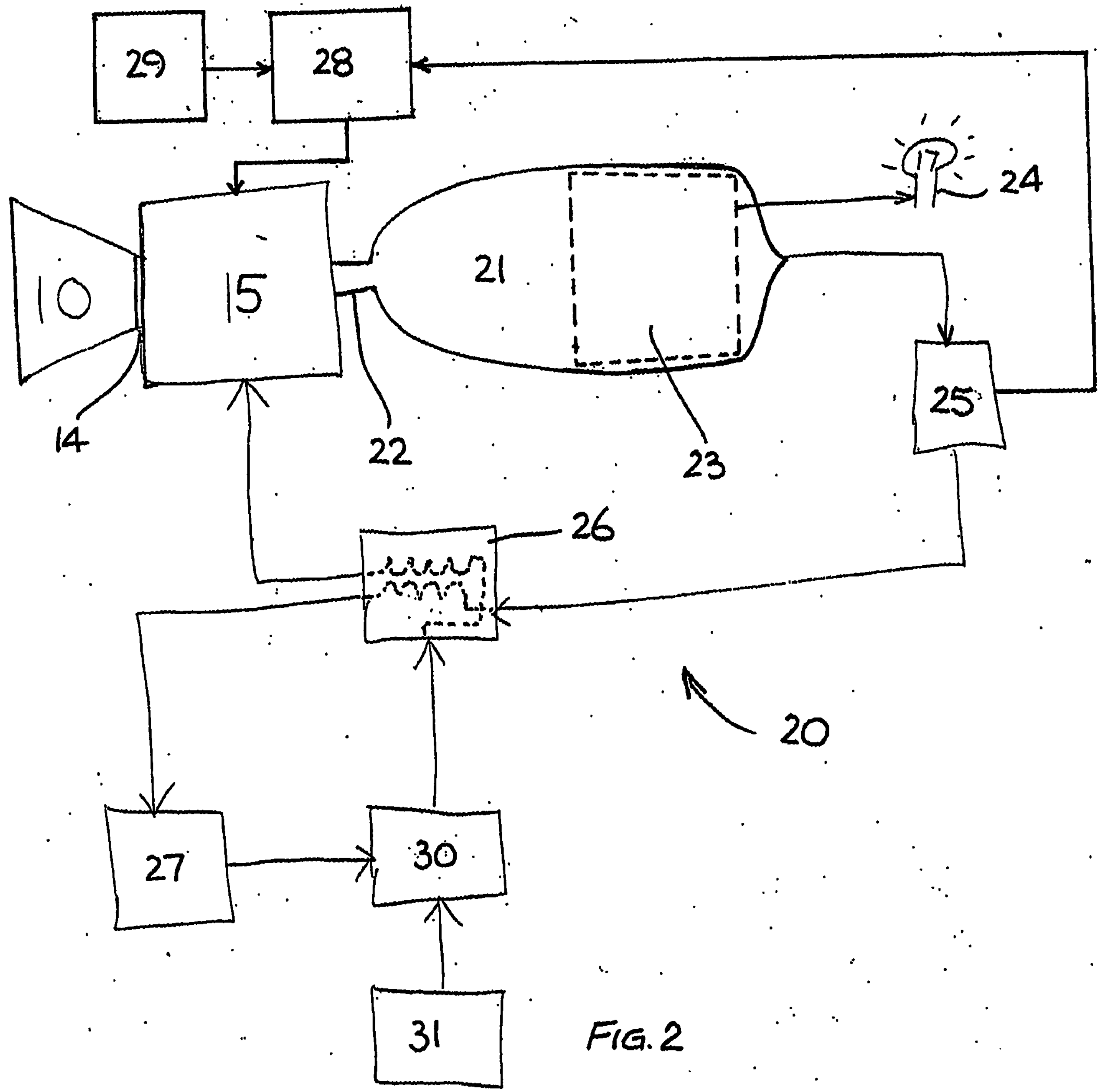

FIG. 2

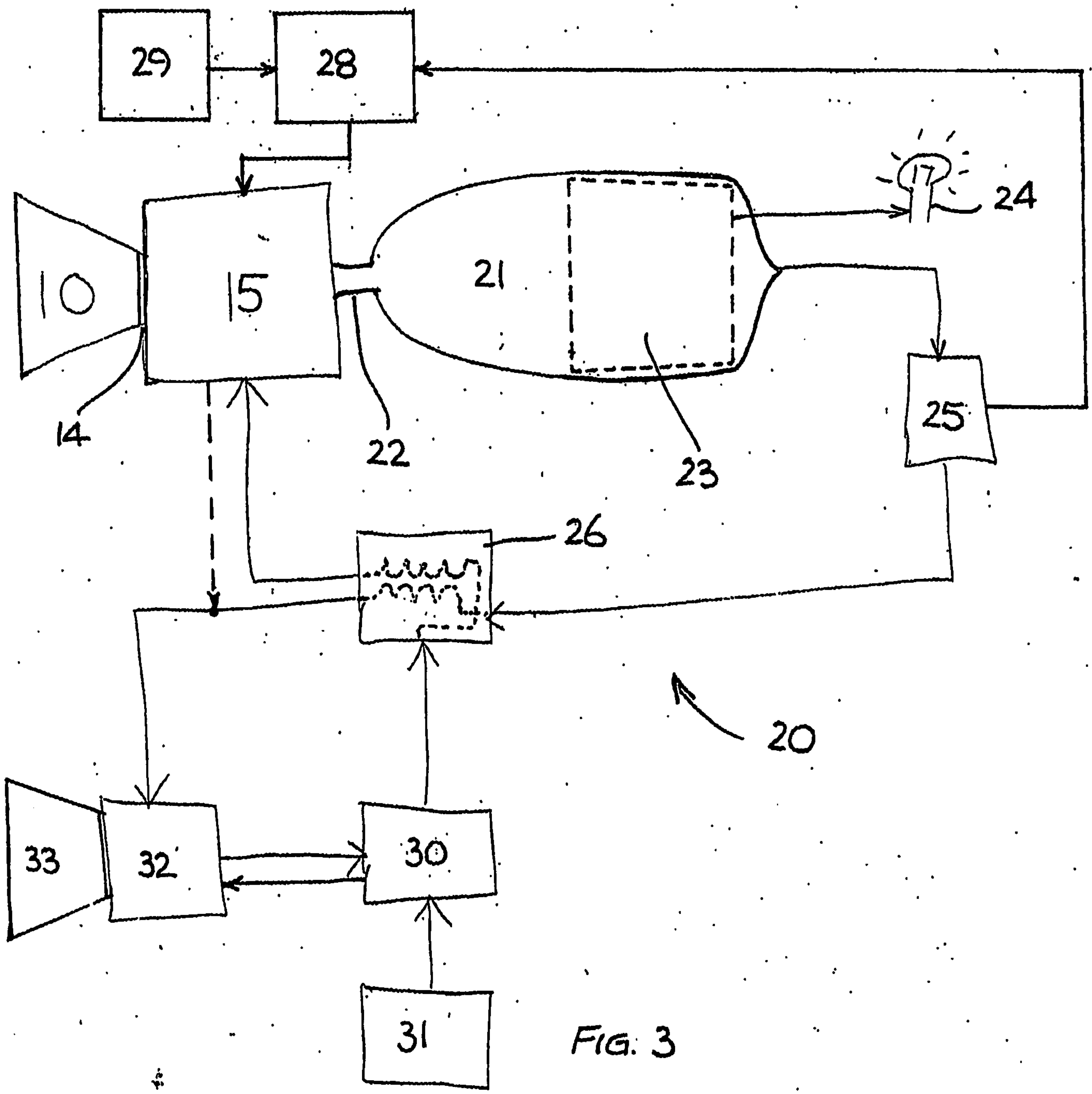

FIG. 3

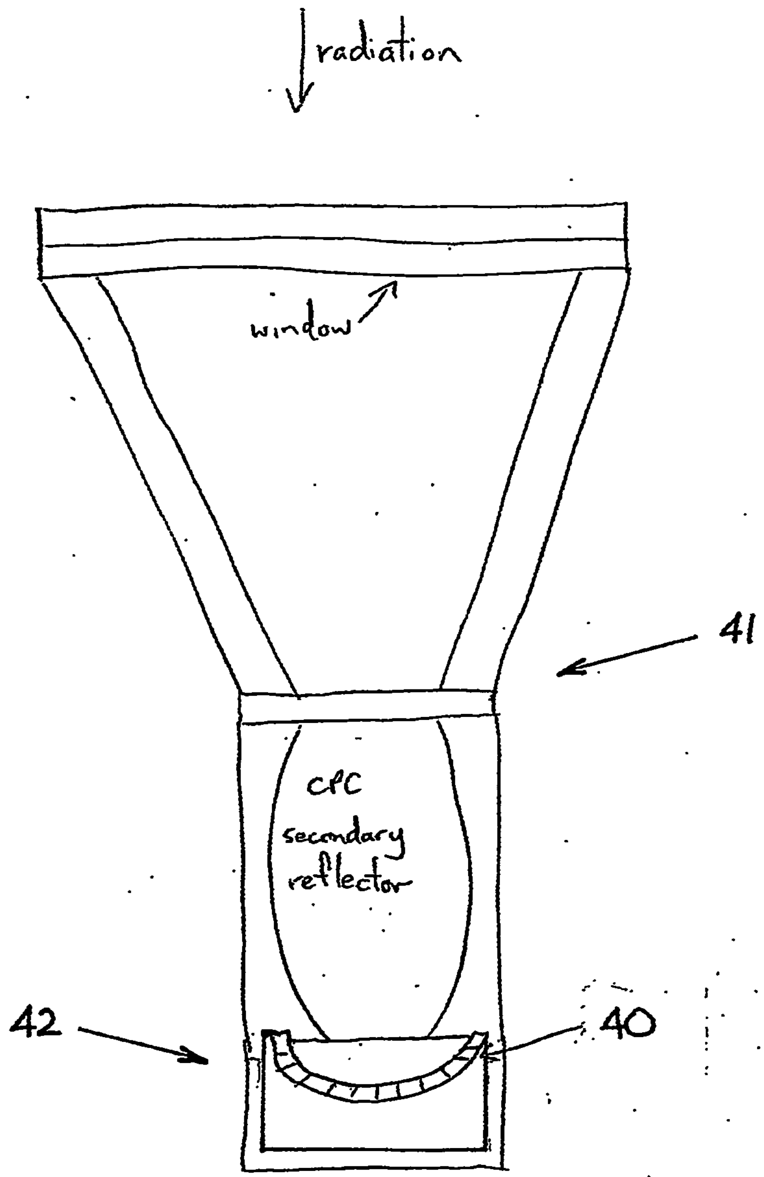

FIG. 4